

ROLES OF MANGROVES IN COASTAL PROTECTION

By

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AP Ahmad Muzaffar Hashim

**Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)**

June 2010

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CERTIFICATION OF APPROVAL

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Approved by,



(AP Ahmad Mustafa Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

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JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



MOHD FAIZ IKHWAN BIN ABDULLAH

ABSTRACT

This project is to research the effectiveness of mangroves plant to act as a coastal protection. After the tsunami in 2004, it can be observed that coastal areas protected by mangroves forest received lesser damages. Malaysia also has some severe problems with the erosion which can be lessen by mangroves. Mangroves have proven to be a potential natural protection especially for areas with low and mild waves. The performance of mangroves varies depending on their physical characteristics and group composition. For this, the study on mangroves effect on wave attenuation in term of wave velocity and wave height was done. Observation during site visit and lab experiments also involved during this research. Experiment done by scaling and modeling natural mangroves trees into smaller model. Wave Flume in Hydraulics Lab used for testing purpose. From the experiments, we observed wave will be attenuated after passing the mangrove model (about 19-28%).Velocity also decreased after passing the mangrove model (about 3-20%).Hence, the findings of this research is that wave attenuated after passing through mangroves forests, leading to decreasing of impact received by coastal areas. It will prove the theory of Mangroves can acts as a natural coastal protection.

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LIST OF ABBREVIATIONS

FRIM	Forest Research Institute Malaysia
DID	Department of Drainage and Irrigation
UTP	Universiti Teknologi PETRONAS

CHAPTER 1

INTRODUCTION

1.1 Background

Mangroves can be defined as trees and shrubs that grow in saline coastal habitat. It is a very diverse and salt-tolerant plants which grew in a large number of population, forming a mangroves swamp. In literature, the term mangrove comes from the Portuguese word *mangue* for “tree” and English word for *grove* for “a stand of trees”. Those terms referring to the appearance of mangroves which they usually stand in group of trees instead of alone.

Basically, mangrove swamp can be found in tropical and sub-tropical tidal areas and it also normal to see mangroves in a coastal area with high degree of salinity which includes estuaries and marine shorelines. This is because even though some plants will destroyed after receiving high level of salinity in the water, mangrove can adapt to these salinity with the help of its special ability. By using reverse osmosis they prevent the salt from getting to the roots and only freshwater will be absorbed. Mangroves also have salt-secreting glands in the leaves that will excrete salt from the tree in case the reverse osmosis did allow some of the salt to entered the roots.

We can observe that at the mangrove swamp, only small percentage of plants grow there that are not from mangroves trees family. This is because the nature of the swamp itself which is semi-stagnant that leads to the muddy substrates to be in anaerobic nature (a state with low level of oxygen to be utilized). Mangrove trees have small pores called *lenticels* at its aerial roots which help them to exchange gases between the roots and atmosphere (Mitsch and Gosselink, 2000). Another function of the aerial roots is to fix them on loose soil of the swamp.

The mangroves roots may be different but they have the same function, it can vary them from other trees. These functions are highly significant for coastal stability and protection. Main types of aerial roots are:

- a) Stilt roots
- b) Pneumatophres
- c) Root knees
- d) Plank roots

Commonly, we can found mangrove forests in river deltas. But it also grows in the exposed shore such as sandy beaches. However, mangrove swamp can only be found in the area with moderate level of wave current. Mangrove forest can be vary into several types based on its hydrological conditions:

- a) Fringe mangroves
- b) Riverine mangroves
- c) Basin mangroves
- d) Dwarf mangroves

Once established, the roots will assist in reducing the water flow which will enhance sediment deposition in areas where it is already occurring. This enhanced sediment helps in reducing the trace metal contamination in the seawater. The theory is that fine sediment will sink the trace metal by creating colloidal particles and sink into the sea bed. Reduced water flow caused by mangrove roots also provides a quiet and calm marine region for young organisms. In areas where roots are entirely submerged, the organisms they host such as algae, oysters, and bryozoans, all required a hard surface for anchoring purpose while they filter feed. While bigger organisms (i.e. shrimps and mud lobsters) use the muddy bottom as their habitats. Others species including mangrove crabs may mulch the mangrove leaves, adding nutrients to the mud for any other bottom feeders. Because of this natural nutrient, the quality of sea creatures is higher compare to any other places.

Other benefit of the mangrove forest is that it acts as an erosion control by slowing the velocity of the wave leading to soil stabilization. Erosion also reduced when the roots spreading the water runoff into wider area of coast and help soil to absorb the impact from the wave maximally. Basically, the mangrove's massive root system is efficient at dissipating wave energy.

Engineers agreed that mangroves can act as a very good natural coastal barrier for stability. It is due to their locations which usually stand in-between between the sea and the land, making them the first defends before wave hit the coastline. Having a highly efficient sediment trapping mechanism, they are considered as an important sink of suspended sediment, thus important for maintaining coastal stability (Katherisan, 2003; Furukawa and Wolanski, 1996). A mangrove forest under a moderate sedimentation rate can accelerate the process of land formation (Cahoon *et al*, 2002).

Another important feature of mangroves significant for coastal stability is their ability to dissipate surface wave energy, reduce wave heights, and decelerate flow of water, thus minimizing soil erosion and damage to properties along the coast (Brinkman, 1999; Hayes-Conroy, 2000; CCRU, 2005; Burger, 2005). Mangroves also react with underwater ecosystems such as seagrass and coral reef communities for coastal protection.

In Malaysia's coastline, one of the major coastal wetland type is the mangrove swamp forest. About 52% of the total length of the Malaysian coastline (40% in Peninsular Malaysia and 60% in Sabah and Sarawak) is mangrove-fringed. For Peninsular Malaysia, mangroves are concentrated at the west coast. And most notable mangroves forest in Peninsular Malaysia is **Matang Mangrove Forest Reserve** along the coast of Perak. Sustainably managed for over 100 years, this dynamic ecosystem generates timber for charcoal products and harbors flourishing fishery commerce.

LOKASI TANAMAN POKOK BAKAU DI PESISIRAN PANTAI NEGARA SEMANJUNG MALAYSIA (TAHUN 2005 - 2008)



Figure 1: Mangroves Forest Location in Peninsular Malaysia (Source : FRIM)

Figure 1 shows area in peninsular Malaysia coastal covered by mangroves forest. We could see that almost all the states happen to have at least 2 mangroves forest site. The highest number of site is at Terengganu with 19 while the lowest one is at Negeri Sembilan with only 2 mangroves forest sites.

Even though mangrove forests commonly grow in river deltas, they also inhabit the exposed shores such as tidal flats or sandy beaches open to the sea, but no extensive forests are likely to develop (Jan de Voz, 2004). Even we take Malaysia as an example to prove the statement; we could see that there are some mangroves forest that populated the peninsular Malaysia located at the open sandy beaches.

Now, we could see that there were a lot of sites been chosen as a location to plant the mangroves trees. For this purpose, we can use 3 different techniques to grow mangroves trees; conventional, comp-mat and comp-pillow.

1.2 Problem statement

After tsunami incident on 2004, most the coastal area in west coast of Peninsular Malaysia damaged badly. But, the situation is different at the coast protected or covered with mangrove forest. It received much lesser damage. So, a study was needed to prove that mangrove can act as a coastal protection measures. And maybe, mangroves also can reduce the erosion on the coastline or beaches. It can be an alternative for water breaker in reducing the wave impact on the coastline.

Besides just protecting the coastline from erosion, a reduced wave will help creating a quite environment for marine habitats. This directly helps in developing the sediment in the seawater and reduces the trace metal contamination.

Awareness on the role of mangrove forests to coastal stability and defense has significantly increased in the recent years, however, the mechanisms and processes associated with it are not sufficiently understood (Jan de Voz, 2004). Knowledge on the interaction between fine-grained mangrove forests with the incoming waves (Moller and Spencer, 2001) and currents, wave transmission and attenuation (Burger, 2005) is vital to achieve sustainable coastal defense management and planning (Moller and Spencer, 2001)

So, a study will be conducted to prove that mangroves can reduce the wave velocity (wave attenuation). Those reduced value may help in reduce the impact of coastal erosion and increase the coastal protection. The increased number of sediments also provided good place for marine habitats and eliminate trace metal contamination.

1.3 Objectives

The objective of this study is to prove that mangroves can play a major role in coastal protection Mangroves can be a potential natural protection especially for areas with low and mild waves. This study also aims to analyze on how wave attenuation in term of wave height and velocity in the mangrove forest will show the effectiveness of mangroves as coastal protection measure.

1.4 Scope of Study

This study will be covering on how mangrove can help to attenuate the wave (wave depth and velocity) coming to the sea before it hit the coastline.

1.5 Relevancy and Feasibility of Project

For many years, Malaysia coastal area has been facing with the erosion problem due to strong wave from the open sea. This situation is so critical that it can become very costly financially for the purpose of maintenance. So, breakwater became a frequent solution for this problem even though the construction of breakwater is also will cost a lot of money and effort, in addition with the problems related to the marine aquatics. So, a natural alternatives should been researched and proved before it can become a much reliable solution for erosion problem. Mangroves been protecting Malaysia coastline for years, yet not enough research was done to prove this.

So, this project mainly purposed to prove that mangroves are efficient to attenuate wave from the open sea. This research will cover the effectiveness in term of coastal protection, approximately 10 months (2 Semesters) timeframe and knowledge from Offshore and Coastal Engineering course is sufficient to ensure the completion of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Mangroves Benefits

According Awang *et al* (1999), mangrove forest is one of the natural resources that exist in the coastal zone. It is the most productive ecosystems on earth, even though individually it considered slow growing and is usually out-competed by faster growing mesophytic tropical trees in non-saline area (Jan de Voz, 2004). Rapid growth rate will make mangroves forest suitable to act as a coastal protection measures. This productiveness will make area covered by mangroves is rapidly increased and more coastal area will be protected in just a short time.

It also been added by Awang *et al* (1999) benefits from the mangrove forests to the coastal area and ecosystems are:

- **Protection of water quality** - mangroves are very effective in trapping sediments from water runoff and groundwater flow.
- **Erosion control** - by stabilizing the soil, reduces the velocity of surface water runoff, reduces erosion by spreading runoff water over a wide area.
- **Protection of coastal habitat** - nesting and feeding by resident or migratory species and cover from predation and climate. Also essential in the ecological and biological processes.
- **Protection of scenic and aesthetic quality** – preserve, protect and restore the scenic value of the coastal region.

2.2 Roles of Mangrove in Wave Attenuation

By the observation, it has been realized that mangroves play a role in supporting marine habitats, stabilizing the coastal zone area and protecting the lives and properties of the peoples living near the sea. It is because mangrove can attenuate the velocity of the wave current. Usually the velocities exceed 1 m/s, but, velocities within a mangrove swamp rarely reach 0.1 m/s (Hadi *et al*, 2003). Figure 2 shows the difference for wave current when it moves passing the mangrove forests and without passing it.

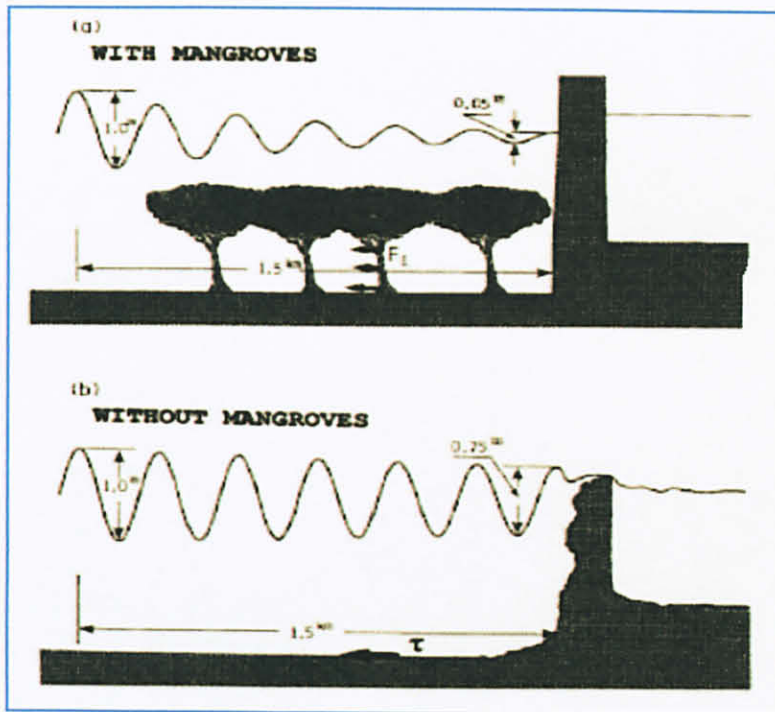


Figure 2: Wave current with/without passing mangrove forests (Source: Jan de Voz, 2004)

Mangroves forest also can stabilize the soil in coastal area by reducing the velocity of wave current. It also can spread runoff water to prevent coastal erosion. Mangrove will act as a natural protection with help of current engineering solution in controlling the erosion such as building hard structures (breakwaters, seawall and groynes). Different from these solutions, mangrove did not interfere with the equilibrium of the natural coastal processes that may result in coastal erosion in other areas, damage to marine ecosystems, and water pollution. It also has advantage in term of cost. To plant fresh mangrove trees cost much lesser than any engineering solutions.

Other mangroves noticeable contribution in coastal protection is during tsunami on 26th December 2004. As one of the worst natural disaster in the history, it responsible for the loss of more than 200 000 lives and millions of dollars of property damage. Although the magnitude of the tsunami waves was high along the affected coast, human losses and property damages were much less in places with healthy mangrove coastal forests, such as in Andaman and Nivobar Islands and Tamil Nadu in India (Osti *et al*, 2008). It can be concluded that mangroves forest along the coastline can reduce the impact taken by shoreline if big waves such as tsunami or rain storm occurred. The protection effectiveness may be control by density, width and age of mangroves forest.

As a wave passes through the mangroves, the orbital motion of the wave particles i.e. the mechanism transmitting the wave energy is obstructed by the roots and the trunks of the mangroves (Othman, 1991). This clearly explained by Figure 3 below.

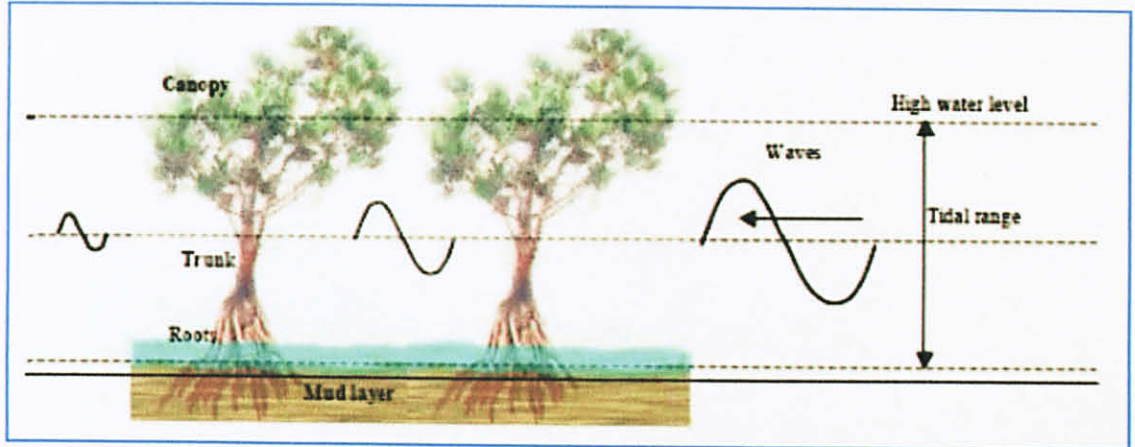


Figure 3: Mangrove will attenuate the wave passing it

It is worth mentioning that efficiency of wave energy dissipation may differ by its ages. Young tree in the mangrove forest along the coast of Thuy Hai, Vietnam have hardly any effect on wave energy reduction compared to sufficiently tall mangrove trees with rate of 20% wave reduction per 100 meters (Jan de Voz, 2004). However, mangroves does not need to be old to act as wave attenuators efficiently, as long it stay close together in a group and as high as the in-coming waves. Generally, a 5 years old new growth of mangroves can already act as wave attenuators (Othman, 1991).

Wave attenuation affected by mangroves trees may depend on depth of the seawater. Exposed roots can cause larger drag force if the water is shallow. Pneumatophores are effective wave dissipaters of small waves (<0.15 meter) in combination with low water levels (<0.30 meter) (Jan de Voz, 2004). In opposite (deep water), roots no longer play pivotal roles as drag force also caused by trunks and canopies located around the higher water level. Thus during storms when high water level exists, more wave energy is attenuated by the high density canopy of the mangrove (Burger, 2005).

It has been shown from field and model results that longer period waves such as swells are subject to less attenuation while short period waves with frequencies typical of locally generated wind waves lose substantial energy due to interactions with the vegetation (Brinkman, 1999; Burger, 2005).

Generally, waves with longer wavelength, will have less velocity changes rates (acceleration or vice versa) compare to the shorter wavelength. The energy lost in its deceleration may followed to next deceleration because of its longer wavelength which causing the energy to remained. In short, shorter waves dissipate more energy compared to a longer wave. Furthermore, more wave energy attenuation is expected in waves with bigger amplitude than smaller ones because of the larger influence depth interacting with the vegetation (Burger, 2005).

In case of water level increases, the wave energy may last longer to the middle of forest since the drag force will be lesser. It is because the ratio of wave current area over cross sectional of forest decreases. Hence, wave attenuation occurred will be lesser. This has been observed in the mangrove forest of Iriomote Island in Japan, where less normalized wave energy is associated with less water depth (Massel *et al*, 1999). But, the situation is not necessarily like that. Wave attenuation can be higher, due to increases of density of mangroves forest. If the density of tree is high enough to distribute along the water area, even when the depth is high it still give large wave reduction.

That theory should be understood in order to increase and provide good assessment regarding mangroves protection on coastal area. Especially during the water level is high such as in case of high storm waves.

2.3 Roles of Mangrove Forest in Sedimentation

Besides decreasing the current velocity by attenuates the wave energy, mangrove also can decrease the wind speed. Bird (1980) observed that offshore winds hardly moved the water surface in a zone up to 20 meters wide in front of mangroves forest, different with the absentees of the mangroves tree when the wind brought sediment towards the shore (Jan de Voz, 2004). This still water, not affected by wind movement will provide a sheltered zone which allows sediment to sink and settled down optimally.

Sediment trapping also can give coastal area more stability and indirectly lead to decreasing of erosion. Water that flows along the mangroves forest usually carries suspended sediment such as fine silt or clay. According to Furukawa and Wolanski (1996), these sediments are cohesive and may form flocs, which remain in suspension due to turbulence created by the flow around vegetation. It means that the suspended sediment will stay in mangroves forest area and the concentration of suspended particles outside the swamp is lower. The suspended particles naturally will settle down and become sediment which make the bank or coastal line stronger and protected from the erosion. Katherisan (2003) studied that concentration of suspended particles inside the mangrove-lined bank ranged from 0.09 to 0.15 g/l while in estuarine and non-mangrove varied only from 0.008 to 0.01 g/l (Figure 4)

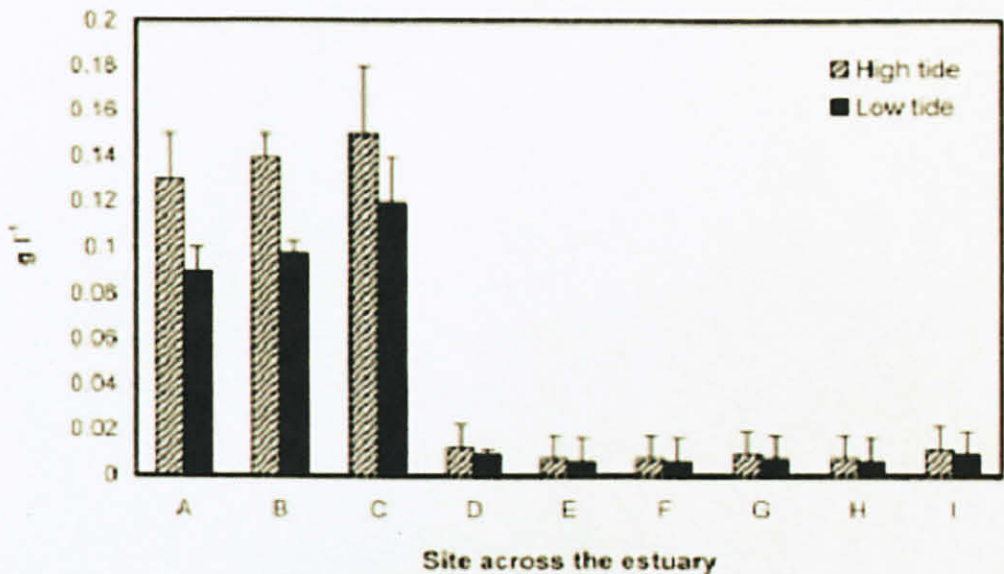


Figure 4 : Average sediment concentration at river bank. Legend: A-C Mangrove-lined bank; D-I Non-mangrove bank (Source: Katherisan, 2003)

Furukawa and Wolanski (1996) also observe that most the sediment brought by the wave, will settle in the mangroves forest. This is because when the suspended sediment in the seawater pass a group of vegetation (Mangroves forest), the calmness of the water will give the sediment chance to sink. As a result, it is clearly the sediment concentration will decrease with the distance from the mangroves forest. With this, Furukawa and Wolanski (1996) asserted that with such evidences, mangroves are not just opportunistic trees colonizing mud banks but actively participate to creation of mud banks.

In the mangrove study area of Katherisan (2003), the effects of zonation and species variation to sedimentation rate were shown. *Avicennia* zone located landward is efficient by removing 25% of the sediments while *Rhizophora* zone along the intertidal area settled only 20%. The highest sedimentation efficiency (30%) was observed in the *Avicennia-Rhizophora* zone, which was attributed to wide spread occurrence of numerous Pneumatophores in *Avicennia* and to compactly arching stilt roots of *Rhizophora*.

Those researches proved previous theory that stated mangrove trees with complex matrix of roots such as *Avicennia-Rhizophora* cause higher intensity of sedimentation compared to single trees like *Ceriops* (Furukawa and Wolanski, 1996). The spacing of mangrove trees will have impact on the sedimentation rate. The drag coefficient will decreased when the density of the forest increase due to wake interference and sheltering (Burger, 2005). We can simplify that drag coefficient is inversely proportional with the density of the forest. The definition of forest density not only limited to the number of trees in the population. It also means the complexation of the roots, some type of tree have a very dense root which did not submerged in the water. The diameters of tree also affecting the drag coefficient of the forest, which make it tend to have higher sedimentation rate.

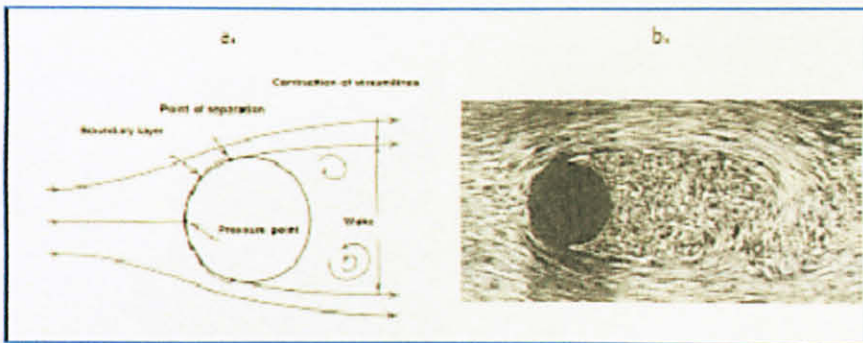


Figure 5: Flow around a cylinder for a theoretical and b, experimental.

2.4 Effects of Mangrove in Adjacent Ecosystems

Besides having high capability to facilitate sedimentation and attenuate wave energy, the mangroves forests also have a significant impact to adjacent ecosystems and vice versa affecting their survival and ecological functioning. Mangroves also can prevent the sediment to be trapped in its swamp instead of spread into the vast sea. Organisms such as coral reefs can live in clear waters. That clear water also helping photosynthesis process for seagrass to occur efficiently compared to process in high turbidity waters. Mangroves also can serves nutrient to seagrass beds. An estimated 21-71% of the sedimentary organic matter pool across different seagrass beds is derived from the mangrove forests (Buillon *et al*, 2004).

CHAPTER 3

METHODOLOGY

3.1 Summary of FYP I

The purpose of this part is to summarize what have been done during FYP I last semester. During the first part of FYP the activities done were:

1. Selection of the FYP titles and Supervisor. Students have been given 2 weeks to choose their own supervisor and freely can propose any titles. I have chosen;

Supervisor : AP Ahmad Mustafa B Hashim
FYP Titles : Roles of Mangroves in Coastal Protection
2. Several journals related to the FYP topics have been reviewed and discussed with supervisor.
3. Attended seminars and classes organized in order to help students with their FYP.
4. A meeting also has been done with an Engineer from Drainage and Irrigation Department (DID) Head-quarters located at Kuala Lumpur. A discussion regarding mangroves plantation in Malaysia was done.
5. By referring to the journals and with the guidance of SV, I have planned on what to do during FYP II so that this project will be completed in time.
6. Submission of reports and oral presentations.

3.2 Research Methodology

During FYPII, two (2) different researches have been taken separately to prove the theory. A site visit and lab session was done in order to completing this project. But, in the end i will only rely on the result of lab session to prove this theory. The reason will be discussed further in this report.

3.2.1 Site Visit

First, a site visit at the mangroves forest was done. This is planned because we need to measure the wave attenuation of the seawater after passing through a group of mangroves from an actual natural condition. A location have been chosen for this visit and forest is ensured matured enough to give us get the best results. **Matang Mangrove Forest Reserve** has been chosen for the sake of this research project.

For this site visit, our researchers' team consists of:

1. AP Ahmad Mustafa Bin Hashim
2. Mohd Faiz Ikhwan Bin Abdullah
3. Farid Mahfuz Bin Abd. Halim
4. Meor Asniwan Meo Ghazali
5. Mohd Idris B Mokhtar
6. Iskandar B Abdul Hamid

Site visit at this mangroves forest was be done for 2 purposes. The first one is that we want to observe mangroves tree from an actual swamp. Some measurement will be taken during this observation.

Conditions of mangrove forests that was planned to be consider during measurement process are:

- 1) Types of mangroves
- 2) Diameter of trees
- 3) Density of mangroves forests
- 4) Length of forests

But, our site visit planned was ruined because inaccessibility to the mangroves site. At **Matang Mangrove Forest Reserve**, the trees been preserved in a very good conditions. But the problem is that it did not react with the wave coming from the sea. To prove the theory of coastal protection, we need mangroves swamp which directly intertidal between sea and coast. So, this forest reserve is not a suitable location to do this research.

Even though we did not be able to complete our site research, we did learn much about mangroves there. We could see on how the appearances of mangroves and its density. It won't helping in our site visit, but this observations were important in second stage of research; lab experiment.



Figure 6: Mangroves Tree



Figure 7: In The Middle of Mangroves Forests

Figure 6 shows on how the mangroves appearances in natural condition. Figure 7 is showing the wider perspective at the forest. During that time, we have been guided by one of the forest ranger to accompany and introduce us to the types of mangroves and other new knowledge regarding to mangroves.

After spending about 45 minutes in the mangroves forest, we then reached at the jetty. After a short discussion, we decided to rent a boat and search for mangroves swamp located intertidal the land and sea. After riding the boat for about 1 hour through fishermen villages and fish cage, we arrived at the delta.

There, we could see a mangroves forest that is very suitable as our research location. But, the boat driver said that the place is inaccessible because of the mud and the water in lower tide compared to tide in the morning. We need to come for another day if we want to continue with our research there. He also said that the place is very muddy that even we can access there, there is no guarantee that we can completed our research as planned.

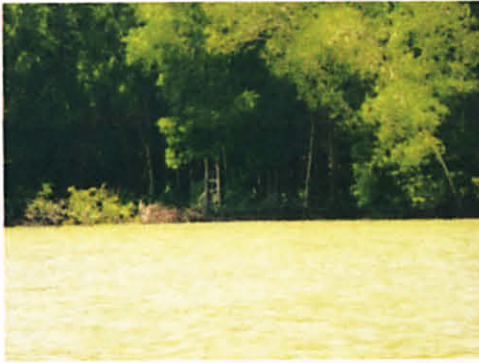


Figure 8 & 9: Mangroves at Delta around Matang Area

On the way back to UTP, we did searching for any other places which is suitable for this research. We did stop at some places at Taiping and also Pantai Remis area. At Pantai Remis we did found a place that is easily accessible. It also sandy which will make our plan to be completed, but yet other problem is that the seawater did not hit the mangroves as the tide is low. So, we just went back to UTP empty handed.

3.2.2 Lab Experiment

Experiment has been conducted to prove that mangroves can act as a coastal protection. To prove the theory, we will look into two (2) matters which are:

1. Wave height
2. Wave velocity

For this experiment, we want to observe if there is any wave attenuation happens for both wave height and velocity. Water Flume at Hydraulic Laboratory will be use and a model will be constructed.

For model, it has been constructed to fit the dimension of the flume which is 30 cm. This model use concrete as its base and for modeling the mangroves tree we use rattan. From plan view, the base model will look like Figure 10 below.

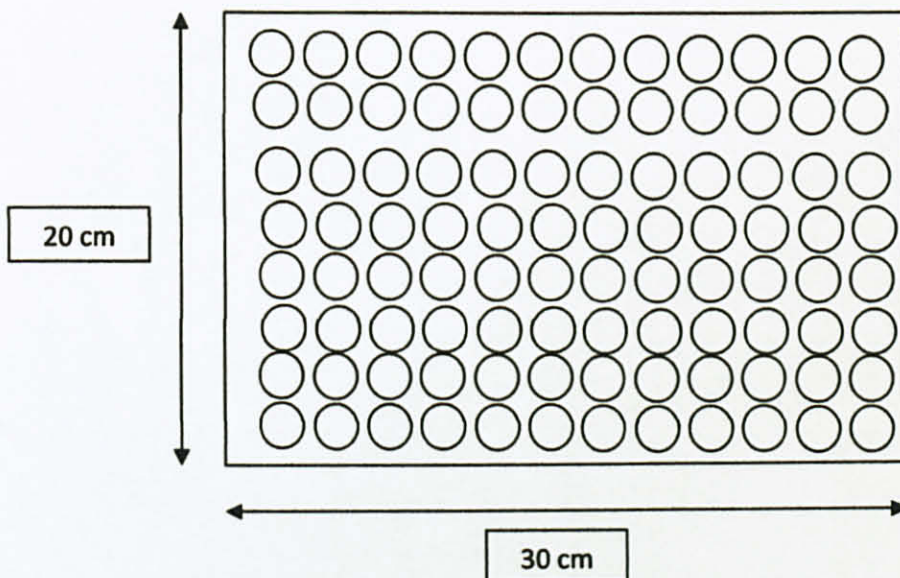


Figure 10: Plan of Mangroves Model

(Figure is not scaled. There should be 60 holes in real model)

We then randomly choose the hole that will inserted by rattan. Average diameter of rattan is 0.05 mm. As been suggested by Hadi *et al* (2003) with a calculation it is decided that 47 mangroves trees will use to represent high density mangroves forest as shown in figure.

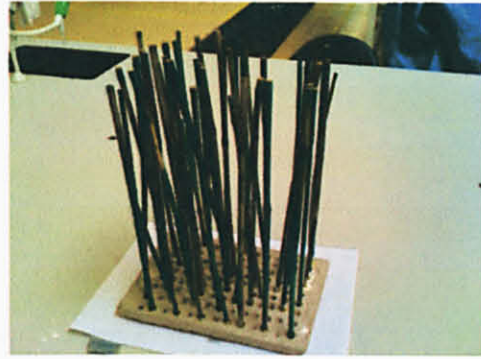
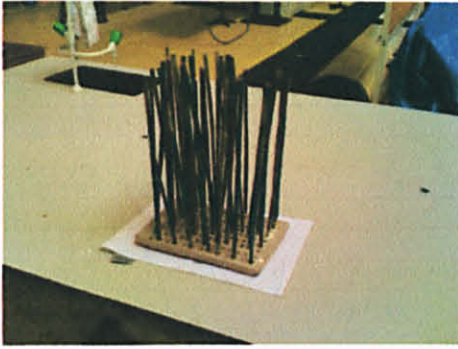


Figure 11 & 12: Model of Mangroves

Then, we will use the model built to do the testing on wave height and wave attenuation. Both of the tests were done in the flume.

3.2.2.1 Wave Height

After the water has been filled into the flume, we will start to create the wave. We will control the frequency start with lower on up until the limit. For this experiment, the test was stopped due to high wave that the model moved slightly which will affecting our observations. We will measure wave height before and after it hit the model. We then can calculate the percentage (%) wave attenuation by taking the difference between both values. The experiment setup shown in figure below:



Figure 13: Wave Passing Through Model

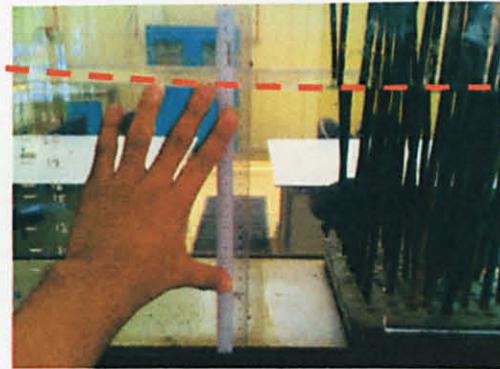


Figure 14: Measuring Wave Height



Figure 15: Upper view of experiment setup

3.2.2.2 Wave Velocity

Instead fill the flume with water; we will let it flow for this test. This is because in 1st setup there is no movement (flow) of water. So, it means no velocity. We will let the water flow passing the model and velocity of current will be measured using Nixon Flowmeter. The reading will be taken before and after it passed the model. After the reading is taken, we will refer to the graph provided by Nixon before velocity in cm/s obtained. We then will calculate the percentage (%) of velocity decreased using both values.

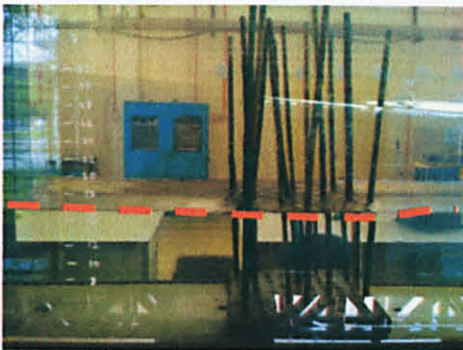


Figure 16: Wave Passing Through Model



Figure 17: Nixon Flowmeter



Figure 18: Gauge Inserted In The Middle of Water



Figure 19: Nixon Flowmeter Reading

After all the data have been taken for mangroves model density of 47 trees per 600 cm^2 , we then change the density by take out some trees model randomly. We make it into tow (2) different densities which were 32 trees per 600 cm^2 (medium density) and 15 trees per 600 cm^2 (low density). Both experiments for wave height and wave velocity repeated for these different densities.



Figure 20 & 21: Mangroves Model with Medium Density (32 trees per 600 cm^2)



Figure 22 & 23: Mangroves Model with Low Density (15 trees per 600 cm^2)



Figure 24: Flume Tank

All the experiment datas obtained will be calculated and discussed further into this report.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results and Calculations

Result shown is obtained from experiments that have been conducted using flume at hydraulic lab. This section will be divided into 2 parts; wave height and wave velocity experiment.

4.1.1 Wave Height

[CASE A]

For density of mangroves = 47 trees per 600 cm²

Parameters: reading is taken 10 cm from the mangroves

Depth = 24 cm

Table 1: Wave Height Difference in High Density Model (d = 24 cm)

<i>f</i>	Wave Height (cm)		Wave Height Difference (cm)	% difference
	initial	final		
0.4386	3.7	2.6	1.1	29.73
0.5371	7.3	5.7	1.6	21.92
0.6353	8.4	7.6	0.8	9.52
0.7407	8.9	6.6	2.3	25.84
0.8375	7	4.6	2.4	34.29
1.0373	9.5	6.9	2.6	27.37
1.2500	10.4	7.2	3.2	30.77
1.4663	12.2	6.6	5.6	45.90

$$\text{Percentage (\%) difference} = \frac{\text{Initial Height} - \text{Final Height}}{\text{Initial Height}} \times 100\%$$

$$\text{Average \% difference} = 28.167 \%$$

Depth = 26 cm

Table 2: Wave Height Difference in High Density Model (d = 26 cm)

f	Wave Height (cm)		Wave Height Difference (cm)	% difference
	initial	final		
0.4386	6	4.9	1.1	18.33
0.5371	5.8	4.5	1.3	22.41
0.6353	9.8	5.5	4.3	43.88
0.7407	7.5	4.7	2.8	37.33
0.8375	8.6	5.8	2.8	32.56
1.0373	13.9	9.7	4.2	30.22
1.2500	10.1	8.1	2.0	19.80
1.4663	6.9	5.5	1.4	20.29

Average % difference = 28.103 %

Depth = 28 cm

Table 3: Wave Height Difference in High Density Model (d = 28 cm)

f	Wave Height		Wave Height Difference	% difference
	initial	final		
0.4386	3.8	2	1.8	47.37
0.5371	5.5	3.8	1.7	30.91
0.6353	6.2	4.9	1.3	20.97
0.7407	9.3	6.6	2.7	29.03
0.8375	9.1	6.2	2.9	31.87
1.0373	11.1	8	3.1	27.93
1.2500	11.4	9	2.4	21.05
1.4663	8	6.6	1.4	17.50

Average % difference = 28.328 %

As we can see from the reading of average percentage (%) difference for different water depth is almost identical. This mean that water depth did not affecting the wave height reading. Hence, for different density of mangroves model we can neglect the water depth variation and just completing 1 experiment for each density.

[CASE B]

For density of mangroves = 32 trees per 600 cm²

Parameters: reading is taken 10 cm from the mangroves

Depth = 26 cm

Table 4: Wave Height Difference in Medium Density Model (d = 26 cm)

<i>f</i>	Wave Height (cm)		Wave Height Difference (cm)	% difference
	initial	final		
0.4386	7.2	6.1	1.1	15.28
0.5371	8.7	6.1	2.6	29.89
0.6353	6.9	4.8	2.1	30.43
0.7407	7.1	4.8	2.3	32.39
0.8375	9.4	7.6	1.8	19.15
1.0373	12.2	10.1	2.1	17.21
1.2500	10.8	9.2	1.6	14.81
1.4663	9.8	6.3	3.5	35.71

Average % difference = 24.360 %

[CASE C]

For density of mangroves = 15 trees per 600 cm²

Parameters: reading is taken 10 cm from the mangroves

Depth = 26 cm

Table 5: Wave Height Difference in Low Density Model (d = 26 cm)

<i>f</i>	Wave Height (cm)		Wave Height Difference (cm)	% difference
	initial	final		
0.4386	3.4	2	1.4	41.18
0.5371	2.4	2.2	0.2	8.33
0.6353	5.8	4.7	1.1	18.97
0.7407	8.7	6.5	2.2	25.29
0.8375	8.1	6.2	1.9	23.46
1.0373	12.4	10	2.4	19.35
1.2500	9.9	8.8	1.1	11.11
1.4663	7.9	7.3	0.6	7.59

Average % difference = 19.410 %

4.1.2 Wave Velocity

[CASE A]

For density of mangroves = 47 trees per 600 cm²

Parameters: Water depth = 16cm

Average flowrate = 44.9 m³/h

Table 6: Wave Velocity in High Density Model

	distance from model (cm)	Velocity (cm/s)		
		top	inter	bed
(-)	0	21.0	15.7	9.0
	30	23.2	18.7	12.6
	50	21.7	18.0	11.7
	100	22.4	19.5	14.2
	150	22.4	20.1	13.5
(+))	0	24.7	21.0	0.0
	30	18.0	15.0	9.6
	50	16.3	14.2	9.0
	100	18.0	12.6	10.4
	150	16.3	14.2	10.4

(-) indicates before wave passing through the model

(+) indicates after wave passing through the model

To calculate the average velocity, we need to find the average value for all the velocity obtained from the experiment.

Average (-) velocity = 17.58 cm/s

Average (+) velocity = 13.98 cm/s

So, Percentage (%) difference =
$$\frac{\text{Initial Height} - \text{Final Height}}{\text{Initial Height}} \times 100\%$$

We get difference of = 20.478 %

[CASE B]

For density of mangroves = 32 trees per 600 cm²

Parameters: Water depth = 18cm
 Average flowrate = 42.7 m³/h

Table 7: Wave Velocity in Medium Density Model

	distance from model (cm)	Velocity (cm/s)		
		top	inter	bed
(-)	0	22.4	19.5	10.4
	30	21.7	19.5	12.6
	50	21.7	20.1	11.7
	100	22.4	20.1	11.7
	150	24.0	21.7	12.6
(+)	0	21.7	18.0	0.0
	30	21.0	17.2	10.4
	50	21.0	18.0	9.6
	100	20.1	18.0	11.2
	150	20.1	17.2	11.2

Average (-) velocity = 18.14 cm/s

Average (+) velocity = 15.65 cm/s

Percentage (%) difference = 13.745 %

[CASE C]

For density of mangroves = 15 trees per 600 cm²

Parameters: Water depth = 16cm

Average flowrate = 47.4 m³/h

Table 8: Wave Velocity in Low Density Model

	distance from model (cm)	Velocity (cm/s)		
		top	inter	bed
(-)	0	29.8	24.0	11.2
	30	30.6	27.4	15.0
	50	31.4	22.4	14.2
	100	29.8	21.7	16.4
	150	32.2	26.2	18.7
(+))	0	28.3	22.4	0.0
	30	27.4	26.2	14.2
	50	28.3	26.2	14.2
	100	32.2	26.2	21.0
	150	28.3	26.2	16.4

Average (-) velocity = 23.40 cm/s

Average (+) velocity = 22.50 cm/s

Percentage (%) difference = 3.846 %

4.2 Discussion

4.2.1 Wave Height

From the values obtained, we could see that mangroves model have affected the wave height in the flume passing it. All the result shown a positive percentage of wave height reduction which mean there is wave attenuation caused by the model. But the effectiveness of wave attenuation may be affected by the density of mangrove forests. For every part of experiment, we have taken data 3 times to ensure its integrity and preventing errors.

For mangroves with the density of 47 trees per 600 cm², we have tried to vary the depth of water to know if depth plays roles in wave attenuation. But, the results showed that while at different depth average wave attenuation did not change much and consistently almost the same.

Table 9: Summary of Wave Attenuation in High Density Model

Depth of Water (cm)	Average Percentage Wave Height Difference (%)
24	28.167
26	28.103
28	28.328

So, for every other density we can only use any depth that is suitable because it did not affecting the value of wave attenuation. But it should be noted that this only valid for mangroves model as we also created the model of trees, there is no roots or canopies on this model. As been discussed in the literature review before, in the natural forest, water depth will affect the attenuation of the wave. Then, after completed the test on both mangroves with the density of 32 trees per 600 cm² and 15 trees per 600 cm², we can summarize the result of wave height differences as below.

Table 10: Summary of Wave Attenuation (Wave Height)

Density of Mangroves Model (trees per 600 cm ²)	Average Percentage Wave Height Difference (%)
47	28.200
32	24.360
15	19.410

From the result above, we could see that wave attenuation increases as the mangroves is denser. We can conclude that in the higher density of mangroves forests, the coastal will be more protected and less impacts received. It is because theoretically, bigger waves will give more impacts and damages to the coastal area.

Hence, we proved that:

1. Wave will attenuated after passing the mangroves forests
2. Density will affect the effectiveness of wave attenuation. The denser the forest is, the higher wave been attenuated.

4.2.2 Wave Velocity

Same with the previous part of experiment and from the values obtained, we could see that mangroves model have affected the wave velocity in the flume passing it. All the result shown a positive percentage of wave height reduction which mean there is wave attenuation (velocity) caused by the model. But the effectiveness of wave attenuation may be affected by the density of mangrove forests. For every part of experiment, we have taken data 3 times to ensure its integrity and preventing errors.

After the experiment been done on every density of mangroves models, we came with the result summarize as below.

Table 11: Summary of Wave Attenuation (Wave Velocity)

Density of Mangroves Model (trees per 600 cm ²)	Average Percentage Wave Velocity Difference (%)
47	20.478
32	13.745
15	3.846

By analyzing the value obtained, we could see the wave velocity difference will be low if the density of mangroves is lesser. In short, in higher density forest the coastal will receive lesser impact because of the decreased velocity of wave. Drag force caused by more number of trees is higher and this have decreased the velocity of wave about one-fifth of initial velocity. Less velocity means less force on the coastal and coastal will be more protected. While for 15 trees, we could see that almost did not have any effect to the velocity. Initial velocity is slightly higher than final velocity. This could mean that mangroves did not help the protection at all if the density is low.

As a conclusion, we proved;

1. Wave velocity will decrease (attenuate) after passing the mangroves forests.
2. Density will affect the effectiveness of wave attenuation. The denser the forest the higher difference of wave velocity will be.

In short, after both of the experiments we can conclude that:

1. Wave will be attenuate after passing the mangroves. This will result in lesser damages received by coastal areas.
2. Density play roles in applying drag force. Hence denser mangroves forest is more efficient in coastal protection.

CHAPTER 5

ECONOMIC BENEFITS

5.1 FYP Research Cost

For this Final Year Project research, experiment has been done to prove that it can attenuate wave height and also wave velocity. “Roles of Mangrove in Coastal Protection” more towards research-based project, not a product-based project. Hence, the costs involved only on cost for obtaining the data and conduct the experiment.

Table 12: FYP Experiment Cost

Activities	Cost (RM)
Data Gathering	
Site Visit to Matang Forest Reserve	150
Experiment	
Concrete Base	10
Rattan	100
Glue	8
Flume, Flowmeter	Provided by Lab
Total	268

5.2 Costs in Mangroves Plantation

Based on the research done by Institut Penyelidikan Perhutanan Malaysia (FRIM) the cost for mangroves plantation can be estimated. Their founding can be found in Ministry of Agriculture (MOA) website. FRIM have stated that cost for mangroves plantation different with the condition of wave.

For slow and mild wave, it is safe to plant new mangroves tree in normal method. The method is that we out in straight on the soil and it can grow by itself as any normal plants. The cost for mangroves seed may vary from **RM0.20 to RM1 per tree**. But seed also can grow without any help by human after it falls down from their mother trees.

While for rougher wave, there are a few methods that are suitable to be used.

1. Comp-pillow method. It cost **RM81.70 per unit** which consists of 5 trees.
2. Bamboo Encasement Method (BEM). This method is upgrade from the Riley Encasement Method (REM). Mangroves plantation will cost **RM4.10 per tree**. But its growth is slow.
3. Comp-mat method. The cost involved is **RM89.95 per unit**.

To choose the best method possible to be use, we may look to certain conditions which will affect our decision. Conditions that can be observed are the wave current speed, budget available and also time provided for this plantation project.

As for its effectives, we can relate it our previous experiment and conclusion. We found out that density can play role in its effectiveness. Hence, the better protection can be achieved if the density is higher. It may not replaced current breakwater, but it greatly help in protecting coastline.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In order to prove that mangroves can play roles in coastal protection, 2 experiments have been conducted using constructed mangroves model. We have done the testing on effect of mangroves on the attenuation of wave height and wave velocity. We also have varied the parameter in term of mangroves density.

We have been able to prove that mangroves will attenuate wave (both velocity and height) that passing through them regardless of their density. Density will affect on the effectiveness of the attenuation. In wave height experiment we obtained for high density forest the decreasing of wave height up to 28.20 % compared to lesser density forest which give decreasing of 24.36% and 19.41%. While in wave velocity experiment high density forest give attenuation value up to 20.478% decreasing in term of velocity. While, for medium and low density forest give 13.745% and 3.846% attenuations respectively.

In conclusion, we have achieved these project objectives. We proved that mangroves can play major roles in coastal protection. They are suitable to act as natural enhancement to current coastal protection. We also have analyzed to show on how level of wave attenuation in term of wave height and velocity in the mangrove forest show the effectiveness of mangroves in coastal protection.

6.2 Recommendation

Based on the research that has been completed, I feel that this project can be expanded more in the future. My recommendations to improve the project are:

- Collaborate with UMT and FRIM as both of them have specialized in mangroves researches.
- Expanding the experiment by vary the parameters of length of models and also width of forest.
- Completing site visit and do some testing on-site instead of just rely on the result of lab experiment.

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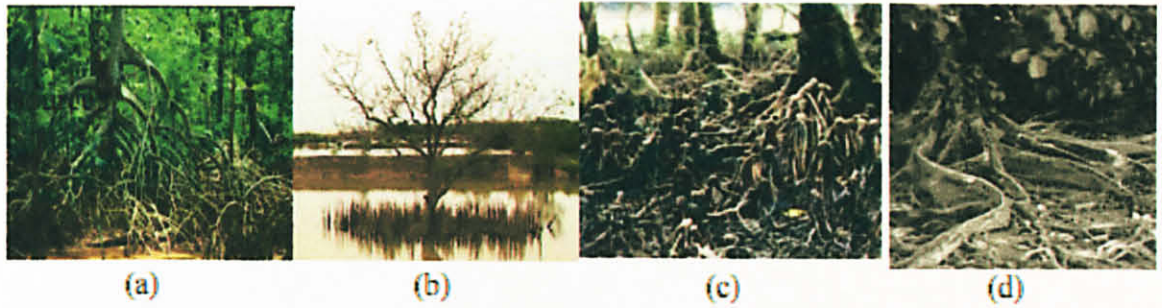
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APPENDICES

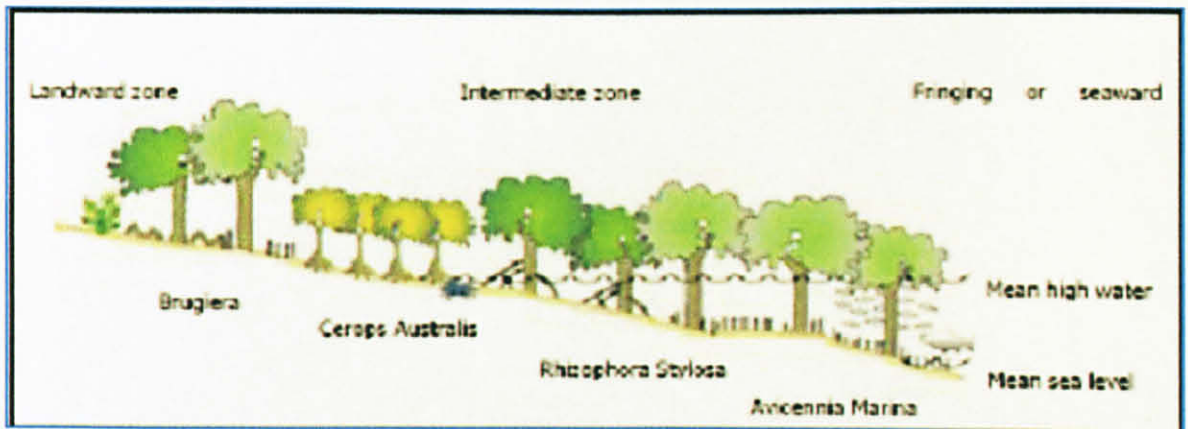
APPENDIX A



Four types of aerial roots structures of mangroves;

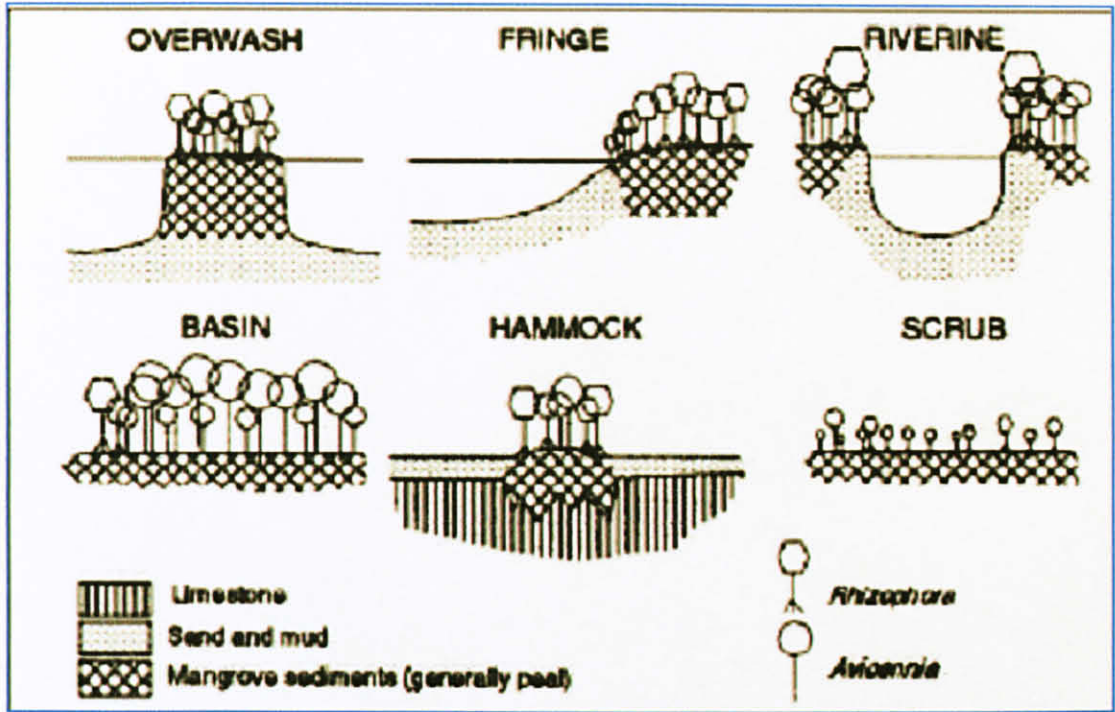
- (a) Stilt Roots
- (b) Pneumatophore
- (c) Knee Roots
- (d) Plank Roots

APPENDIX B



Hypothetical schematization of zonation in a mangrove forest (Source; Burger, 2005)

APPENDIX C



Different types of mangrove forests base on hydrological conditions

APPENDIX D

Mangroves plantation

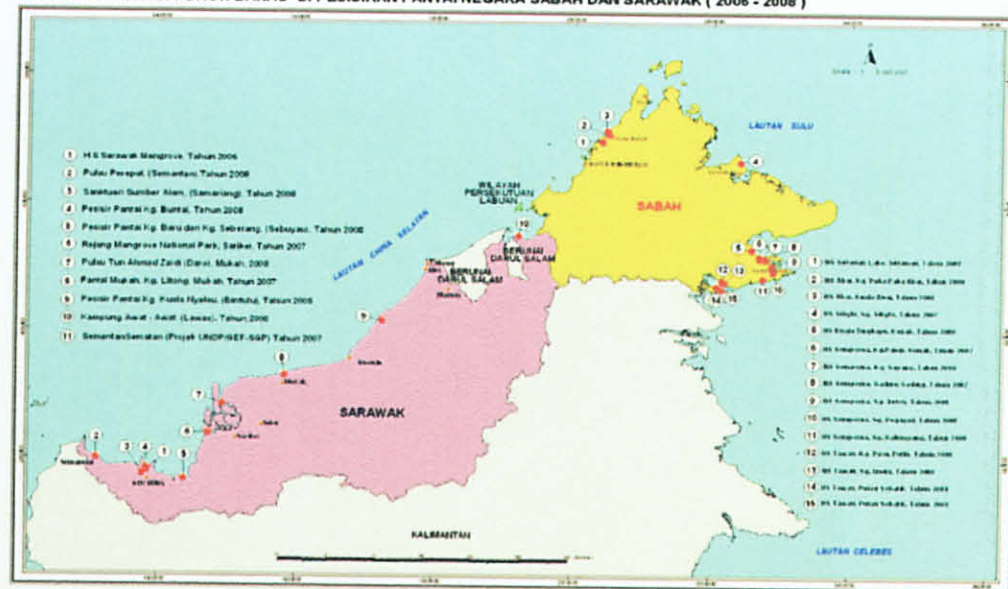


APPENDIX E

LOKASI TANAMAN POKOK BAKAU DI PESIRAN PANTAI NEGARA SEMANGUNG MALAYSIA (TAHUN 2005 - 2008)



LOKASI TANAMAN POKOK BAKAU DI PESIRAN PANTAI NEGARA SABAH DAN SARAWAK (2006 - 2008)



Locations of mangroves forest in Malaysia

APPENDIX F



View in the middle of mangrove forests

APPENDIX G



Types of Mangroves at Matang Mangroves Forest Reserve



Dynamism of Mangroves Forest